APPENDIX A

GEOPHYSICAL SURVEY REPORT

Geophysical Survey Report
Former Decontamination Complex, Building 1271
Parcels 93(7), 46(7), 140(7), and 70(7)

Fort McClellan, Alabama

July 2003

Table of Contents

Page

List of Figures ii

List of Acronyms iii

A.1.0 Introduction A-1-1

A.2.0 Field Procedures A-2-1

A.2.1 Survey Control A-2-1

A.2.2 Geophysical Survey A-2-1

A.2.2.1 Magnetic Survey A-2-2

A.2.2.2 Time-Domain EM Survey A-2-3

A.2.2.3 Frequency-Domain EM Survey A-2-4

A.2.2.4 Anomaly Verification, GPR Survey, and Sampling Locations A-2-5

A.3.0 Data Processing A-3-1

A.4.0 Interpretation of Geophysical Data A-4-1

A.4.1 Data Interpretation Criteria A-4-1

A.4.2 Former Decontamination Complex Data Interpretation A-4-3

A.5.0 Conclusions and Recommendations A-5-1

Attachment - Theoretical Background

List of Figures

Number	Title
A-1	Vicinity Map
A-2	Site Map with Geophysical Interpretation
A-3	Contour Map of G-858G Total Magnetic Field, Upper Sensor
A-4	Contour Map of EM61 Bottom Coil (N-S Survey Lines)
A-5	Contour Map of EM61 Bottom Coil (E-W Survey Lines)
A-6	Contour Map of EM31 Conductivity (N-S Survey Lines)
A-7	Contour Map of EM31 In-Phase Component (N-S Survey Lines)
A-8	Contour Map of EM31 Conductivity (E-W Survey Lines)
A-9	Contour Map of EM31 In-Phase Component (E-W Survey Lines)
A-10	GPR Lines 20 E and 25 E, 400-MHz Antenna
A-11	GPR Line 40 N, 400-MHz Antenna

List of Acronyms

AGC	automatic gain control
CD	compact disk
E-W	east to west
EBS	Environmental Baseline Study
EM	electromagnetic induction
EM31	Geonics Limited EM31 Terrain Conductivity Meter
EM61	Geonics Limited EM61 High-Resolution Metal Detector
FDC	Former Decontamination Complex
FTMC	Fort McClellan
G-856AX	Geometrics, Inc. G-856AX magnetometer
G-858G	Geometrics, Inc. G-858G magnetic gradiometer
GPR	ground penetrating radar
GPS	global positioning system
GSSI	Geophysical Survey Systems Inc.
IT	IT Corporation
MHz	megahertz
mS/m	millisiemens per meter
mV	millivolts
NAD	North American Datum
NOAA	National Oceanographic and Atmospheric Administration
N-S	north to south
ns	nanoseconds
nT	nanoteslas
ppt	parts per thousand
RTK	real-time kinematic
SSFSP	Site-Specific Field Sampling Plan
TERC	Total Environmental Restoration Contract
USACE	U.S. Army Corps of Engineers
UST	underground storage tank

A.1.0 Introduction

Shaw Environmental, Inc. (Shaw), formerly IT Corporation (IT), conducted a surface geophysical survey at the Former Decontamination Complex (FDC), [Parcels 93(7), 46(7), 140(7), and 70(7)], at Fort McClellan (FTMC) in Calhoun County, Alabama, on October 30, 1998, February 10, 1999, March 7 through March 16, 1999, and May 8, 1999. The survey was conducted for the U.S. Army Corps of Engineers (USACE) – Mobile District, under Total Environmental Restoration Contract (TERC) No. DACA21-96-D-0018, Delivery Order CK005. The geophysical survey objective was to locate buried metal potentially representing underground storage tanks (USTs). Based on the criteria established in the Site-Specific Field Sampling Plan (SSFSP) for UST identification, anomalies that are typical in size and in logical areas for USTs (i.e., adjacent to typical FTMC gas station foundations) are identified and labeled as USTs. Anomalies that are either a typical size or in a logical location for USTs are labeled as potential USTs. The area surveyed was approximately 10,800 square feet (0.25 acres). The Vicinity Map (Figure A-1) shows the approximate location of the FDC survey area.

To accomplish the objectives of the investigation, an initial site-screening survey was conducted using magnetic and electromagnetic (EM) methods. Ground penetrating radar (GPR) was later used in an effort to discriminate between magnetic and EM anomalies caused by the target USTs and those caused by other subsurface features, such as utility vaults, or pits containing significant metallic debris. All geophysical data were processed and color-enhanced to aid in interpreting subtle anomalies. Following geophysics fieldwork, a survey-grade global positioning system (GPS) was used to document the location of the FDC site.

The FDC site topography is relatively flat. The site is primarily grass covered with areas of asphalt, gravel, and concrete, as shown on the site map with geophysical interpretation (Figure A-2).

Field procedures used during the investigation are described in Chapter A.2.0. The data processing methods used during the investigation are presented in Chapter A.3.0. Data interpretation and techniques used to rank geophysical anomalies as to their potential to be caused by tanks is presented in Chapter A.4.0. Conclusions and recommendations derived from the geophysical surveys are presented in Chapter A.5.0. A description of the equipment and a theoretical discussion of the geophysical methods are presented in the Attachment.

A.2.0 Field Procedures

This chapter describes the field procedures and instruments used to conduct the investigation, including survey control, data acquisition, and field verification of geophysical anomalies.

A.2.1 Survey Control

The geophysical survey area to be investigated was identified in the site-specific work plan based on historical site information compiled by Shaw and the Environmental Baseline Study (EBS), (ESE, 1998). The geophysics crew established a base grid on 100-foot centers throughout the site. Using the base grid as a reference, the crew marked control points on 10-foot centers with surveyor's paint to provide the spatial control required for the investigation. Due to the uncertainty of true field positions inherent when establishing a survey area using 300-foot fiberglass tapes in the presence of wind and surface obstructions (e.g., trees, vehicles, and structures), the lateral precision for the survey areas and anomalies is estimated to be within +/- 1 foot. Following geophysics fieldwork, a GPS survey was conducted at the site referencing the U.S. State Plane Coordinate System (Alabama East Zone, North American Datum [NAD] 1983). The GPS survey was performed in the real-time kinematic (RTK) mode, which provided nominal sub-centimeter resolution in XY coordinates for the site.

A detailed site map was hand-drawn in the field. The map included any surface cultural features within the survey area, or near its perimeter, that could potentially affect the geophysical data (e.g., vehicles, overhead utilities, manhole covers). The map also shows reference features, such as buildings, fences, asphalt patches, and survey monuments that could later aid in reconstructing the site boundaries. All pertinent reference information documented on the hand-drawn site map was placed on the site interpretation map (Figure A-2). Also included on the site map are GPS coordinates to help relocate the survey area.

A.2.2 Geophysical Survey

Field Instruments. The magnetic instruments used during the investigation consisted of a Geometrics Inc. G-858G magnetic gradiometer (G-858G) for collecting survey data and a Geometrics G-856AX used for collecting magnetic base station data. Time-domain EM induction equipment consisted of a Geonics EM61 High-Resolution Metal Detector (EM61) coupled to an Omnidata DL720 digital data logger. Frequency-domain EM induction equipment consisted of a Geonics EM31 Terrain Conductivity Meter (EM31) coupled to an Omnidata

DL720 digital data logger. Ground penetrating radar equipment consisted of a Geophysical Survey Systems Inc. (GSSI) Model SIR-2P unit coupled to 200- and/or 400-megahertz (MHz) antennae and a DPU-5400 thermal gray-scale printer. Where required, a Metrotech 9860-BRL EM utility locator was used to verify that linear anomalies seen in the EM31/EM61 data were caused by subsurface pipelines or utilities. A Trimble 4000SSI Total Station GPS was used to conduct the civil survey work.

All geophysical data were collected using the following Shaw standard operating procedures:

- ITGP-001 Surface Magnetic Surveys
- ITGP-002 Surface Frequency-Domain Electromagnetic Surveys
- ITGP-003 Ground Penetrating Radar Surveys
- ITGP-004 Surface Time-Domain Electromagnetic Surveys
- ITGP-005 Global Positioning System Surveys
- ITGP-012 Geophysical Data Management.

The three geophysical techniques of magnetics, time-domain EM, and frequency-domain EM, were used initially to screen the survey area for large buried metal objects the size of a UST. These combined methods offer the technical approach most likely to succeed in locating and delineating large metal objects. Following magnetic and EM data processing and interpretation, GPR was used to aid with interpreting the anomalies observed in the magnetic and EM maps. The GPR survey was focused only on those anomalies potentially caused by a UST.

Field Instrument Base Station. A field instrument base station was established at FDC to provide quality control for the geophysical survey data collected at the site. The base station location was chosen to be free of surface and subsurface cultural features that could affect the geophysical data. Standard field procedures were to occupy the base station and collect readings with the survey instruments (magnetic, EM31, and EM61) before and after each data collection session. These base station data were then reviewed to assess instrument operation. Opening and closing base station file names and average data values were recorded on base station summary forms.

A.2.2.1 Magnetic Survey

Magnetic Base Station. A magnetic base station was established at FTMC to record the background fluctuation (diurnal drift) of the Earth's magnetic field. The magnetic base station was located in a field of small pine trees on the south side of Sixth Avenue (near Parcel 151).

The magnetic base station location was determined to be free of surface and subsurface cultural features that could affect the data. A G-856AX magnetometer was used for the magnetic base station, however, instrument problems were later identified that precluded its use in "drift correcting" the G-858G survey data. National Oceanographic and Atmospheric Administration (NOAA) regional magnetic field data representing the time period of the magnetic survey were later reviewed, and it was determined that the survey was conducted during a time of quiescence in the Earth's magnetic field. The variation of the regional geomagnetic field during data collection was less than 10 nanoteslas (nT), which is considered negligible for obscuring anomalies caused by USTs.

G-858G Data Collection. Magnetic field measurements were made with the two sensors of the G-858G spaced 2.5 feet (0.76 meters) apart; the lower sensor was 2.0 feet above the ground surface and the upper sensor was 4.5 feet above the ground surface. At the start and end of each data collection session, approximately 60 readings were recorded with the G-858G at the field instrument base station to verify that the instrument was operating properly, and to provide a quantitative record of instrument variation, during the survey period. A review of these base station files indicated the instrument was operating properly and the instrument drift was within acceptable limits. Magnetic survey data were collected at 0.5-second intervals (approximately 2.0- to 2.5-foot intervals) along north to south (N-S) oriented survey lines spaced 10 feet apart, for a total of approximately 1,150 linear feet of survey coverage.

The magnetic data were stored in the internal memory of the G-858G along with corresponding line and station numbers and the time of acquisition. Magnetic survey data were screened in the field to assess data quality prior to completing the investigation. All magnetic survey and base station data were downloaded to a personal computer, backed up on IOMEGA® compatible zip disks, and are retained in project files.

A.2.2.2 Time-Domain EM Survey

EM61 Data Collection. Prior to conducting the EM61 survey, the instrument was calibrated to read zero at the field instrument base station. The EM61 was operated in the wheel mode with manual triggering, and readings of the potential difference measured in the top and bottom coils were collected. At the start and end of each data collection session approximately 20 readings were recorded at the field instrument base to verify that the instrument was operating properly, and to provide a quantitative record of instrument variation, or drift, during the survey period. A review of these base station files indicated the instrument was operating properly and instrument drift was within acceptable limits. Survey data were collected at 2.5-foot intervals along N-S and east to west (E-W) oriented survey lines spaced 5 feet apart, for a total of approximately 4,400 linear feet of survey coverage. The EM61 data were acquired along perpendicular survey lines to define anomalies potentially caused by subsurface utilities and improve the geophysical interpretation of EM61 anomalies as they relate to possible USTs.

The EM61 data were stored in the digital data logger with corresponding line and station numbers. EM61 line profiles were reviewed in the field using the DAT61® program to verify data quality prior to completing the survey. All EM61 survey and base station data were downloaded to a personal computer, backed up on IOMEGA® compatible zip disks, and are retained in project files.

A.2.2.3 Frequency-Domain EM Survey

EM31 Data Collection. Prior to conducting the EM31 survey, the instrument was calibrated and the in-phase component zeroed at the field instrument base station. The instrument was operated in the vertical dipole mode measuring the in-phase and out-of-phase components of the secondary EM field. At the start and end of each data collection session approximately 20 readings were recorded at the field instrument base station to verify that the instrument was operating properly, and to provide a quantitative record of instrument variation, or drift, during the survey period. A review of these base station files indicated the instrument was operating properly and instrument drift was within acceptable limits. Survey data were collected at 5-foot intervals along N-S and E-W oriented survey lines spaced 10 feet apart, for a total of approximately 2,300 linear feet of survey coverage. The EM31 data were acquired along perpendicular survey lines to provide a clear definition of anomalies potentially caused by subsurface utilities and improve the geophysical interpretation of EM31 anomalies as they relate to possible USTs.

The EM31 data were stored in the digital data logger with corresponding line and station numbers. EM31 line profiles were reviewed in the field using the DAT31® program to verify data quality prior to completing the survey. All EM31 survey and base station data were downloaded to a personal computer, backed up on IOMEGA® compatible zip disks, and are retained in project files.

A.2.2.4 Anomaly Verification, GPR Survey, and Sampling Locations

Anomaly Verification. Preliminary color-contour maps of the magnetic, EM61, and EM31 data were generated and field-checked to differentiate between anomalies caused by surface and subsurface sources. Geophysical anomalies verified as being caused by surface features were labeled as such on the field data maps. Geophysical anomalies suspected to be caused by underground utilities were verified with an EM utility locator. The locations of confirmed utilities were placed on the site map. Anomalies caused by buried metallic objects potentially representing a UST were carefully located in the field and marked on the site map for further characterization with GPR.

GPR Data Collection. Ground penetrating radar data were collected to discriminate between EM and magnetic anomalies potentially caused by USTs from those caused by significant buried metallic debris, metal reinforced utility vaults and junction boxes, and localized concentrations of metal. GPR data is also useful to identify USTs near objects such as buildings, fences, and reinforced concrete pads, which tend to mask the signature of the UST in the EM and magnetic data. The GPR survey included acquisition of approximately 3,900 linear feet of data using the 200- and 400-MHz antennas. The digital GPR data were recorded continuously (32 scans per second) as the antenna was hand-towed across the survey lines. Control points were marked on the GPR records using a hand-held switch located on the antenna unit. The GPR data were field-reviewed in real time on a color monitor, stored in the internal memory of the instrument, and later downloaded to a personal computer. The GPR data were printed in the field as the survey progressed using a high-resolution thermal gray-scale printer. All GPR survey data were backed up on compact discs (CD), and are retained in project files.

Sampling Locations. After the geophysical data interpretation was complete, all anomalies interpreted to be caused by USTs or potential USTs, were marked on the ground in the field, so that project personnel could later sample these locations in accordance with the SSFSP sampling rationale.

A.3.0 Data Processing

Color Contour Maps. Contour maps of magnetic, EM61, and EM31 data were generated using the OASIS Montaj® geophysical mapping system from Geosoft, Inc. These maps were color-enhanced to aid with interpreting subtle anomalies. Select contour maps from this site are presented as Figures A-3 through A-9.

A series of data processing steps were required to generate the contour maps. G-858G magnetic gradiometer data were downloaded from the field instrument and converted to an ASCII file using Geometrics, Inc. MAGMAP® program. EM61 and EM31 data were downloaded from the data loggers and converted to ASCII files using DAT61® and DAT31® software from Geonics, Inc. The ASCII data files were then reviewed to assess line numbers, station ranges, and overall data quality. Field data file names and corresponding base station data files were recorded on the data file tracking form. Data screening results were then recorded on the base station summary form. Following data quality assessment, geometry corrections to field data files were made, if necessary, using a text editor and recorded on the geophysical data editing form.

Final, corrected magnetic and EM data files containing local geophysical station coordinates (X,Y) and the geophysical measurement (Z) were converted to OASIS Montaj® format and imported into the geophysical mapping software. All data files within the Geosoft database were reviewed in profile form to verify completeness of data editing. The data were then gridded with the bi-directional gridding module using an Akima spline. The grid cell size for the magnetic, EM61, and EM31 data was chosen to be 2.5, 1.25, and 2.5 feet, respectively. A color-contouring scale was selected to enhance data anomalies of interest to this investigation. The names of files generated and processing parameters used were recorded on data processing forms. Final processed map names are shown in the data processing box found in the lower left corner of each contour map presented. All completed forms of magnetic and EM data collected during the investigation are retained in project files.

GPR Profiles. Select GPR profile data were processed using the Gradix® data processing and interpretation system from Interpex Limited, and are presented as Figures A-10 and A-11. The GPR data were trace balanced and gained using an automatic gain control (AGC) function. A color amplitude scale was then chosen to enhance features of interest. Following GPR processing, the data were imported to Microsoft WORD® to produce color figures. GPR data file names are shown below each profile. All GPR data are stored on CDs and retained in project files.

A.4.0 Interpretation of Geophysical Data

The method by which the geophysical data were interpreted, and the results of that interpretation are presented in this chapter.

Figure A-2 presents the site map with geophysical interpretation. The interpreted color-contour map of G-858G total magnetic field for the upper sensor is presented as Figure A-3. Interpreted color-contour maps of EM61 bottom coil data acquired along N-S and E-W survey lines are presented as Figures A-4 and A-5, respectively. Interpreted color-contour maps of EM31 conductivity and in-phase component data collected along N-S survey lines are presented as Figures A-6 and A-7, respectively. Interpreted color-contour maps of EM31 conductivity and in-phase component data collected along E-W survey lines are presented as Figures A-8 and A-9, respectively. Representative GPR profiles characterizing Anomaly A-1(3) identified in the EM and magnetic data are presented in Figures A-10 and A-11. The locations of these GPR profiles are shown on Figure A-2. A theoretical background is presented as an Attachment to this report. The attachment discusses the factors influencing the observed geophysical response for the various methods and equipment used to conduct the FDC survey.

In addition to the geophysical interpretation and GPR line locations, the site map (Figure A-2) contains detailed information on reference features (e.g., asphalt and concrete pavement, buildings, and fences), so that the survey area and the geophysical anomaly locations can be relocated in the future. Anomalies shown on the site interpretation map correspond to those seen in the magnetic, EM, and GPR data. Surface reference features shown on the site interpretation map were translated from the hand-drawn site map made in the field. The site interpretation map also references the Alabama East State Plane, North American Datum 1983 Coordinate System.

A.4.1 Data Interpretation Criteria

Color Contour Map Anomalies. Anomalies shown on the magnetic and EM contour maps range from high to low values and from negative to positive, depending on the type of data displayed. The observed anomalies in the contour map of G-858G total magnetic field for the upper sensor have values above and below the average magnetic field intensity of 50,800 nT for Anniston, Alabama. The typical magnetic data response to near-surface ferrous metallic debris is an asymmetric south high/north low signature. The upper sensor magnetic data are more useful than the lower sensor data for locating large buried objects, such as USTs because the lower sensor is more sensitive to small near-surface objects; hence the upper sensor magnetic data are presented. The characteristic EM61 response over a buried metal object shows a positive-amplitude signal, with signal strength dependent upon the size of the object, distance from the transmitter/receiver coils, and the type of material. Upper and lower receiver coil readings are processed to determine a differential value that can be used to approximate the depth of source objects in the data. Although all EM61 data were evaluated during interpretation, only the bottom coil EM61 data is presented in the report because these data are most sensitive to buried metal objects. The characteristic EM31 anomaly over a near-surface metallic conductor consists of a narrow zone having strong negative amplitude centered over the target and a broader lobe of weaker, positive amplitude on either side of the target. As the depth of the target feature increases, the characteristic EM31 response changes to a positive amplitude centered over the target.

Anomalies present on the contour maps of magnetic, EM61, and EM31 data were first field-checked and correlated with known metallic surface objects and other cultural surface features so that anomalies caused by subsurface sources could be determined. Many of the high-amplitude anomalies seen in the contour maps of the magnetic, EM61, and EM31 data (Figures A-3 through A-9) are caused by cultural features including fences, reinforced concrete, underground utilities, and metallic debris. These anomalies, as well as anomalies identified to be caused by source objects the size of a UST, are labeled on each of the contour maps and are discussed in the following text. Several anomalies that are interpreted to be caused by discrete buried metal objects smaller than a UST are not discussed in the text.

UST Anomaly Identification. Each anomaly potentially caused by a UST is designated by an alphanumeric symbol with a ranking number in parenthesis on the geophysical interpretation map, color-contour maps, and GPR profiles. The number shown in parenthesis indicates the anomaly type and potential for the source object to be a UST. Geophysical anomalies most likely to be caused by USTs are designated with a (1) in parenthesis. Geophysical anomalies with a ranking of (2) are more uncertain and may be interpreted as a metallic source object other than a UST, although there is potential for the anomaly to be caused by a UST. Anomalies with a ranking of (3) are highly uncertain and generally interpreted to be caused by a source object other than a UST.

The qualitative numerical ranking of anomalies is based on the geophysical response from all the methods used to conduct a survey, although the ranking is heavily weighted on the GPR system response. Rank (1) anomalies most often occur at open sites away from surface and subsurface cultural interference, and at very small sites where a geophysical survey is conducted to confirm the existence of a tank in a specified area.

Typically in open areas, a rank (1) geophysical anomaly shows the following characteristics in the data:

- High-amplitude signal strength in two or more of the site-screening methods (magnetic, EM61, and EM31 data)
- Location in an area that cannot be linked to another possible source object (e.g., buried utility, structures, and fences)
- Source geometry seen in the GPR reflection data that is consistent with a UST.

Clearly in the portions of the site near surface cultural interference, it is highly unlikely for a geophysical anomaly to be ranked (1), even though the source object seen in the data could be a tank. Most rank (2) anomalies have the potential to be a UST, but often lack conclusive GPR data over the source object. Rank (2) anomalies typically show favorable magnitude and signal characteristics in the magnetic and EM data; however, since the dimensions and geometry of the source object may not be resolved and mapped, the feature is not ranked (1). Rank (3) anomalies usually occur in one or two data sets and the results lack conclusive GPR data over the source object. Rank (3) anomalies are interpreted to be caused by a source object other than a UST.

According to the SSFSP criteria anomalies that are found of typical size and in logical areas for USTs (i.e., adjacent to typical FTMC gas station foundations) will be identified and labeled as USTs. Anomalies that are of typical sizes but not in logical locations will be labeled as potential USTs.

A.4.2 Former Decontamination Complex Data Interpretation

One geophysical anomaly not explained by known surface or subsurface cultural features is labeled A-1(2) on the data maps and profiles and discussed below.

Anomaly A-1(2). Anomaly A-1(2) appears as a moderate amplitude anomaly in the E-W EM31 data (Figures A-8 and A-9) centered at approximately (22E, 40N). A large negative response (less than –50mS/m, less that 30 ppt) centered at approximately 22E, 50N is seen in the N-S data. A buried metal object or the masking effect of a nearby reinforced concrete pad could cause the geometry of the EM31 response as anotated on the N-S EM31 maps. The anomaly is not apparent in either the magnetic data (Figure A-3) or EM61 data (Figures A-4 and A-5) due to the masking effect of a nearby reinforced concrete pad. GPR (Figures A-10 and A-11) indicate a buried object that corresponds with the location of the EM31 anomaly along Lines 20 East and 25 East from 37 N to 42 N. Based on the GPR data, the depth of the source object is estimated at

2 to 3 feet. The geometry of the source object seen in the GPR data is consistent with that of a tank. For this reason, Anomaly A-1(2) is interpreted to be caused by a single large buried metal object, possibly a small UST. According to the criteria established in the SSFSP for UST identification, Anomaly A-1(2) is a potential UST since it does not represent a typical size for a 10,000-gallon UST, but is located in a logical area for a UST.

This anomaly location was marked in the field so that project personnel could place the soil and groundwater sample locations in accordance with the SSFSP sampling rationale.

A.5.0 Conclusions and Recommendations

A surface geophysical survey using magnetic, EM and GPR methods was conducted from October 30, 1998, February 10, 1999, March 7 through March 16, 1999, and May 8, 1999 at the Former Decontamination Complex. The objective of the survey was to locate buried metal potentially representing USTs.

One geophysical anomaly potentially caused by a UST was identified in the data from the Former Decontamination Complex. The source of this anomaly is located at approximately (22E, 40N). According to the criteria established in the SSFSP for UST identification, Anomaly A-1(2) is a potential UST since it does not represent a typical size for a 10,000-gallon UST, but is located in a logical area for a UST.

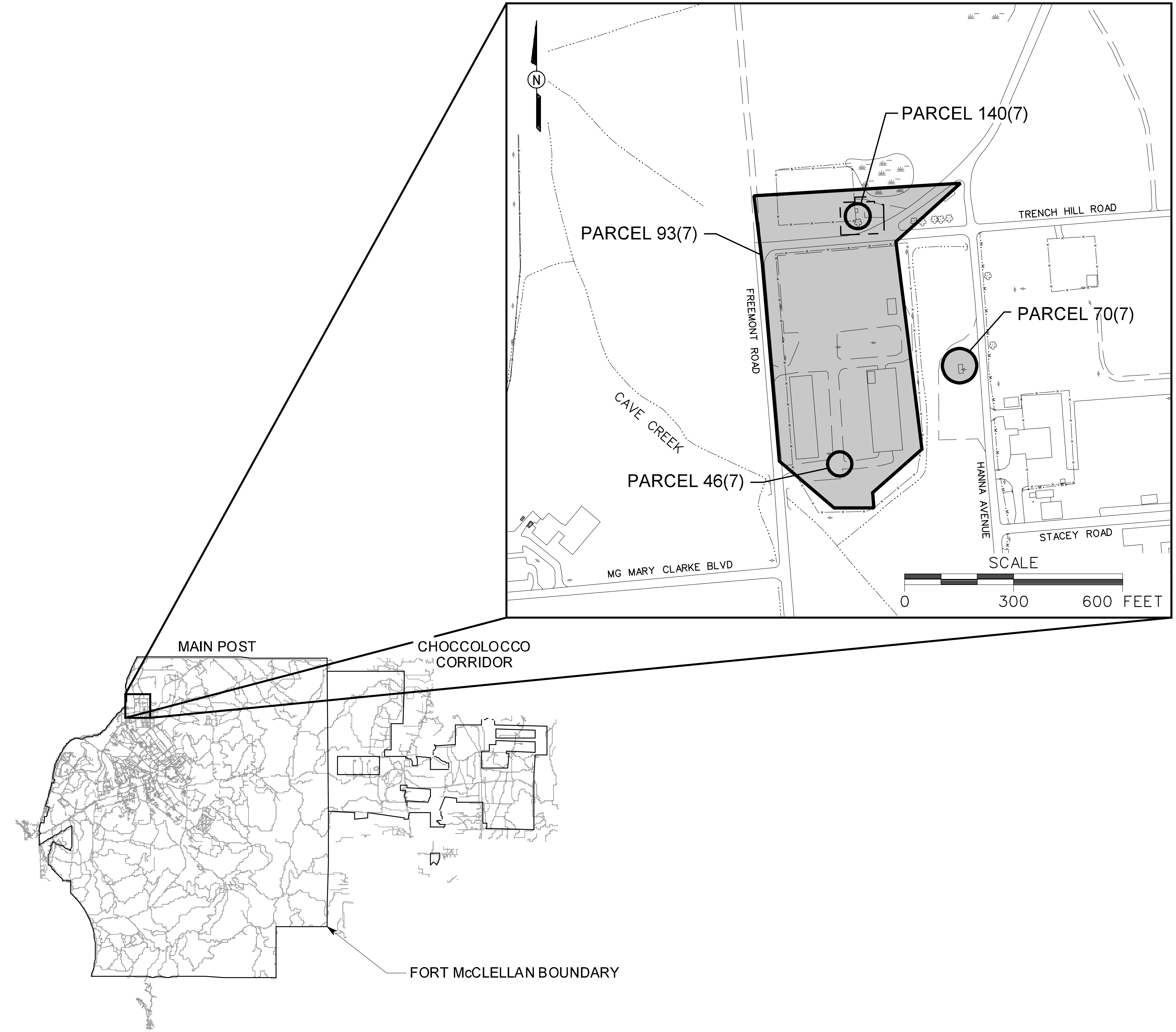
The anomaly location was marked in the field so that project personnel could place the sample locations in accordance with sampling rationale.

A hand sketched site map and GPS survey of site features provided a permanent record of the survey boundaries and anomalies located. Positions on the geophysical interpretation map (Figure A-2) are conservatively estimated to be accurate to within +/- 1 foot.

Pipeline locations are indicated on the site interpretation map where evident in the geophysical data. However, the map should not be considered clearance for exploratory trenching or other invasive investigations. Should such clearance be necessary, Shaw recommends proper geophysical clearance using available utility maps, an EM utility locator, and GPR.

Beyond the recommendation above, and based on the objectives and results of the geophysical survey presented in this report, no further geophysical work is recommended at the Former Decontamination Complex site.

DWG. NO.: ...\774645es.384
PROJ. NO.: 774645
INITIATOR: M. MAKI
PROJ. MGR.: J. YACOUB
DRAFT. CHCK. BY:
ENGR. CHCK. BY: M. MAKI
DATE LAST REV.:
DRAWN BY:
STARTING DATE: 09/14/99
DRAWN BY: D. BOMAR
12/10/2003
4:10:47 PM
c:\cadd\design\774645es.384
dbomar



LEGEND

- UNIMPROVED ROADS AND PARKING
- PAVED ROADS AND PARKING
- BUILDING
- TREES / TREELINE
- MARSH / WETLANDS
- PARCEL BOUNDARY
- GEOPHYSICAL SURVEY BOUNDARY
- SURFACE DRAINAGE / CREEK
- MANMADE SURFACE DRAINAGE FEATURE
- FENCE
- UTILITY POLE

FIGURE A-1
SITE LOCATION MAP
FORMER DECONTAMINATION COMPLEX
PARCELS 93(7), 46(7), 70(7),
AND 140(7)

U. S. ARMY CORPS OF ENGINEERS
MOBILE DISTRICT
FORT McCLELLAN
CALHOUN COUNTY, ALABAMA
Contract No. DACA21-96-D-0018

Shaw Environmental, Inc.

DWG. NO.: ...\774645es.461
PROJ. NO.: 774645
INITIATOR: S. TAKATA
PROJ. MGR.: J. YACOUB
DRAFT. CHCK. BY:
ENGR. CHCK. BY: J. HACKWORTH
DATE LAST REV.:
DRAWN BY:
STARTING DATE: 01/31/00
DRAWN BY: D. BOMAR
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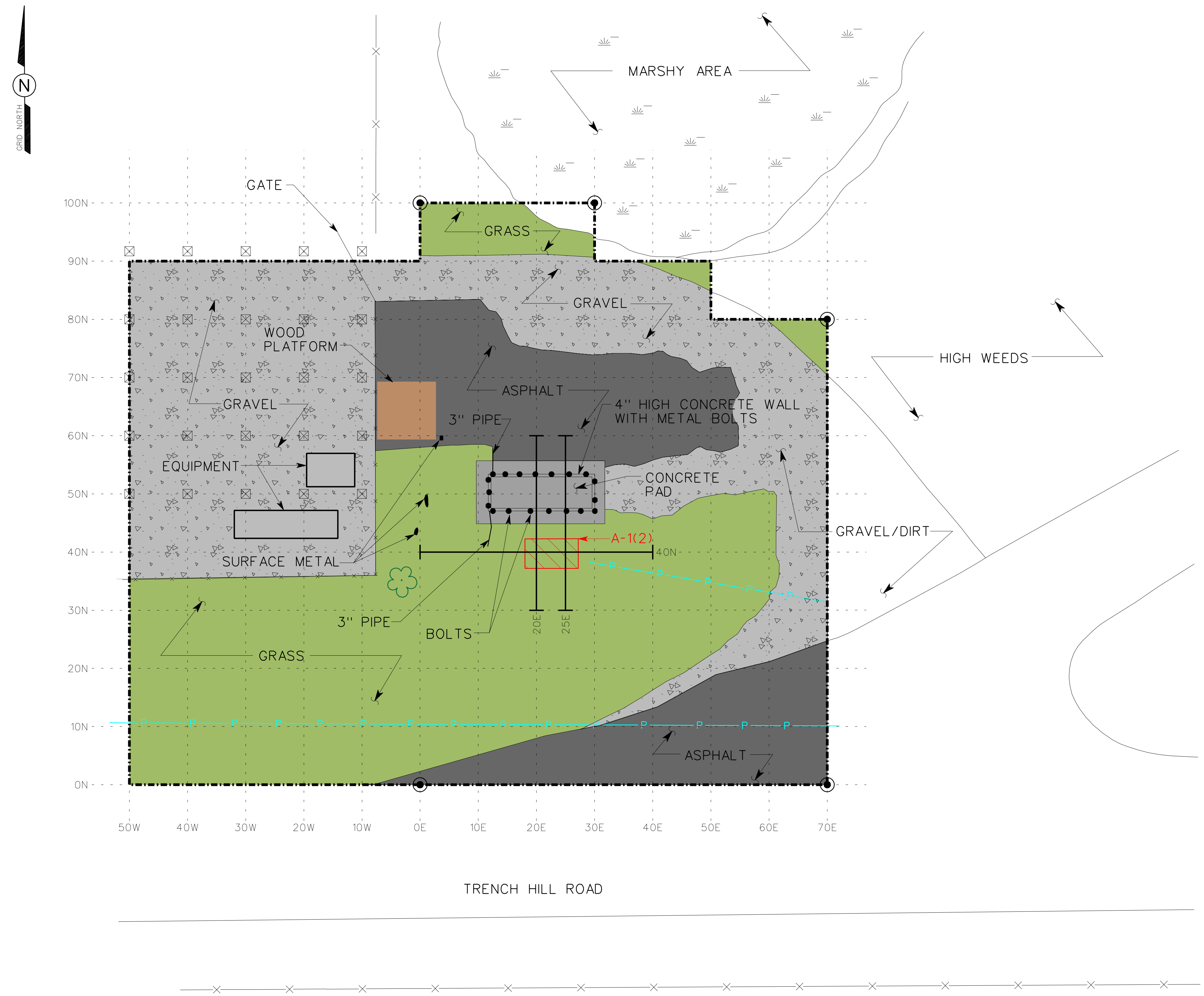
dbomar



LEGEND

- GEOPHYSICAL SURVEY BOUNDARY
- CIVIL SURVEY STAKE LOCATION
- 40N GPR PROFILES PRESENTED
- A-1(2) GEOPHYSICAL ANOMALY DISCUSSED IN TEXT; NUMBER SHOWN IN PARENTHESIS INDICATES ANOMALY TYPE FOR POTENTIAL UST
- 5" x 8" CONCRETE FOOTINGS SOME WITH BOLTS AND METAL FLANGES
- P PIPE/BURIED UTILITY
- FENCE
- TREES / TREELINE
- MARSH / WETLANDS

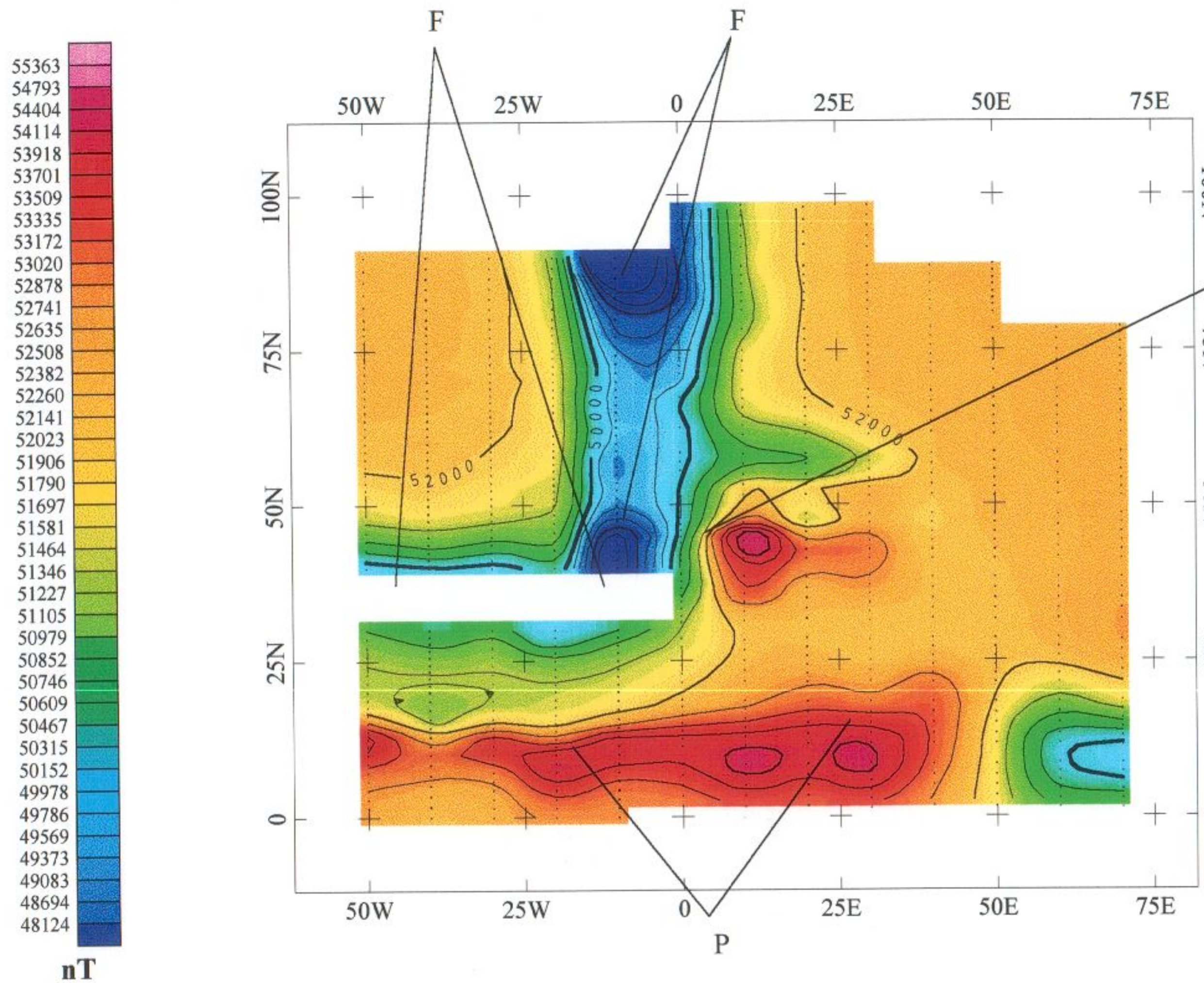
NAD 83 SPHEROID, ALABAMA EAST STATE PLANE DATUM		
LOCAL GRID COORDINATES	STATE PLANE COORDINATES	
0N,0E	1177760.814N	669163.674E
0N,70E	1177766.546N	669233.003E
80N,70E	1177845.893N	669227.028E
100N,30E	1177861.635N	669185.484E
100N,0E	1177861.320N	669154.980E

SCALE
0 20 40 FEET

FIGURE A-2
GEOPHYSICAL INTERPRETATION MAP
FORMER DECONTAMINATION COMPLEX
PARCELS 93(7), 46(7), 70(7),
AND 140(7)

U. S. ARMY CORPS OF ENGINEERS
MOBILE DISTRICT
FORT McCLELLAN
CALHOUN COUNTY, ALABAMA
Contract No. DACA21-96-D-0018

Shaw Environmental, Inc.



LEGEND:

...	GEOPHYSICAL SURVEY LINES	
RC	ANOMALY CAUSED BY REINFORCED CONCRETE	
P	ANOMALY CAUSED BY BURIED PIPES OR UTILITY	
F	ANOMALY CAUSED BY A FENCE	

Scale 1:360

25 0.0 25

feet

Contour Interval: 250 nanoTeslas

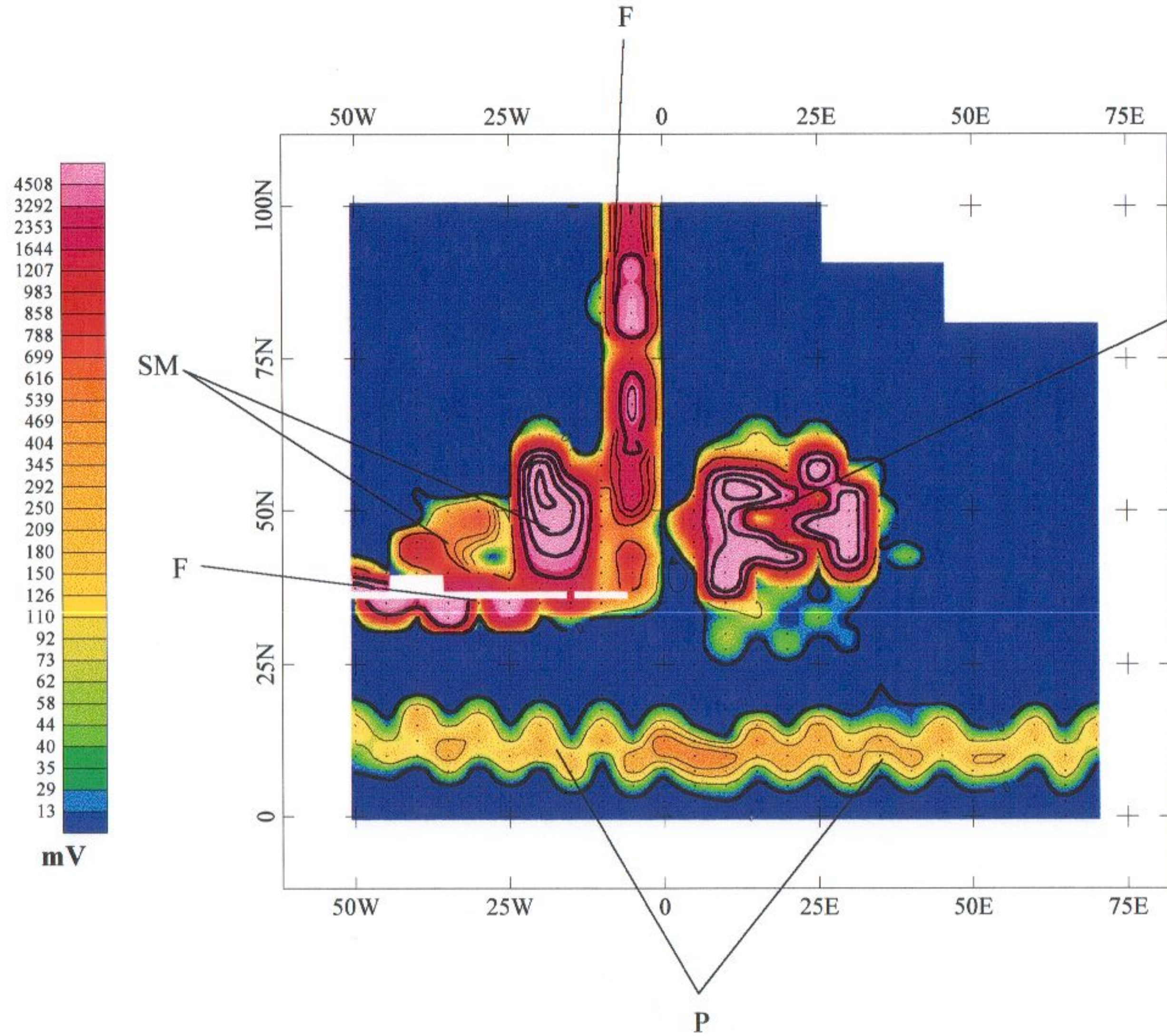
FIGURE A-3

FORT McCLELLAN
SITE - FORMER DECONTAMINATION COMPLEX BLDG 1271

G-858G TOTAL MAGNETIC FIELD
UPPER SENSOR (4.5 FT ABOVE GROUND SURFACE)
N-S SURVEY LINES

GEOPHYSICS GROUP KNOXVILLE, TENNESSEE

NAME: Micki Maki	DATE: July 14, 1999
PROJECT NUMBER: 774645	LOCATION: C:\Projects\Fort McClellan\Decon\MAG\MUP2.map



LEGEND:

...	GEOPHYSICAL SURVEY LINES
RC	ANOMALY CAUSED BY REINFORCED CONCRETE
P	ANOMALY CAUSED BY BURIED PIPES OR UTILITY
F	ANOMALY CAUSED BY A FENCE
SM	ANOMALY CAUSED BY SURFACE METAL

Scale 1:360

25 0.0 25

feet

Contour Interval: 100 milliVolts

FIGURE A-4

FORT McCLELLAN
SITE - FORMER DECONTAMINATION COMPLEX BLDG 1271

EM61 POTENTIAL DIFFERENCE
BOTTOM COIL (1.5 FT ABOVE GROUND SURFACE)
N-S SURVEY LINES

GEOPHYSICS GROUP KNOXVILLE, TENNESSEE

NAME: Micki Maki	DATE: July 14, 1999
PROJECT NUMBER: 774645	LOCATION: C:\Projects\Fort McClellan\Decon\EM61\nB2.map

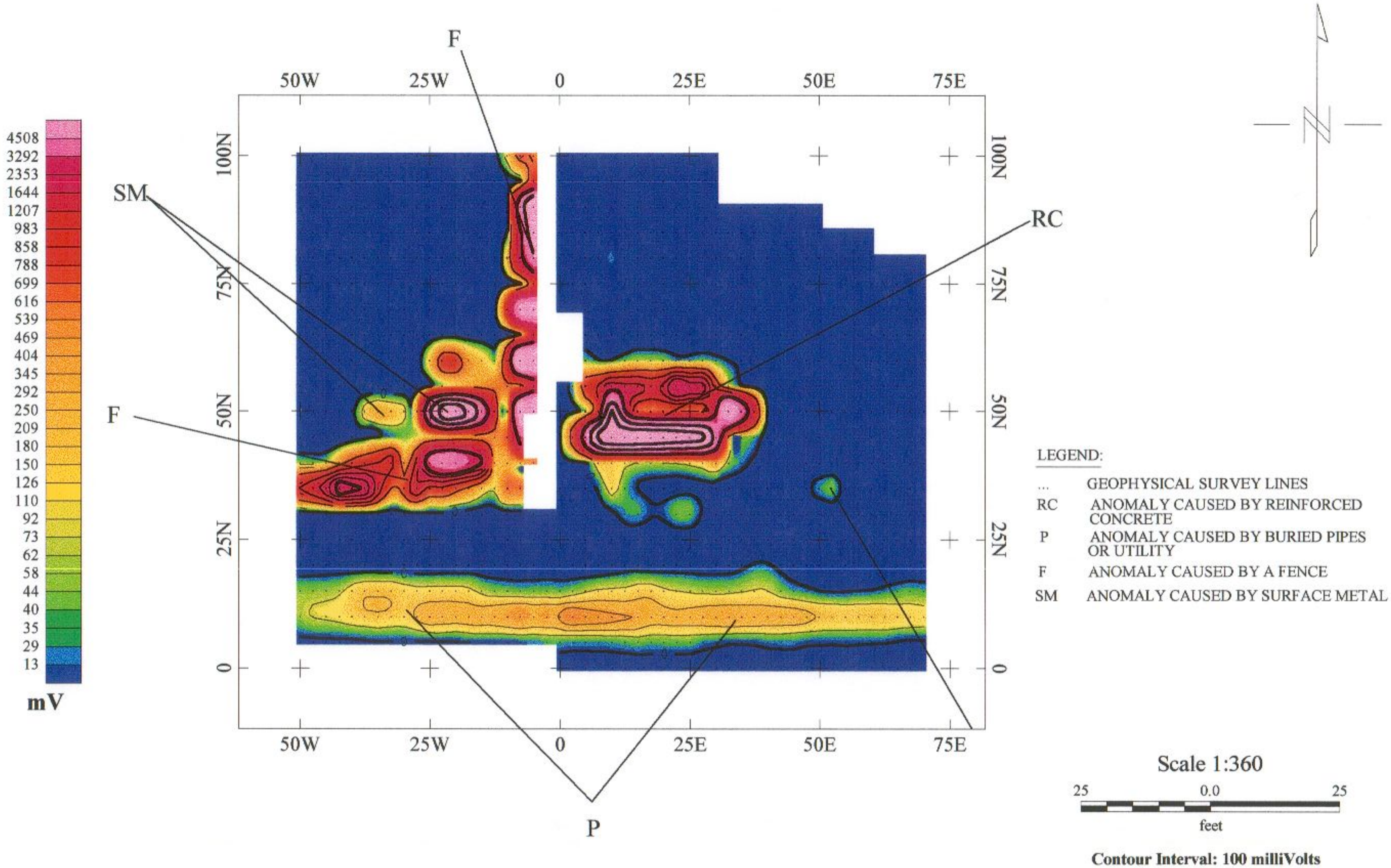


FIGURE A-5

FORT McCLELLAN
SITE - FORMER DECONTAMINATION COMPLEX BLDG 1271

EM61 POTENTIAL DIFFERENCE
BOTTOM COIL (1.5 FT ABOVE GROUND SURFACE)
E-W SURVEY LINES

GEOPHYSICS GROUP KNOXVILLE, TENNESSEE

NAME: Micki Maki	DATE: July 14, 1999
PROJECT NUMBER: 774645	LOCATION: C:\Projects\Fort McClellan\Decon\EM61\eB2.map

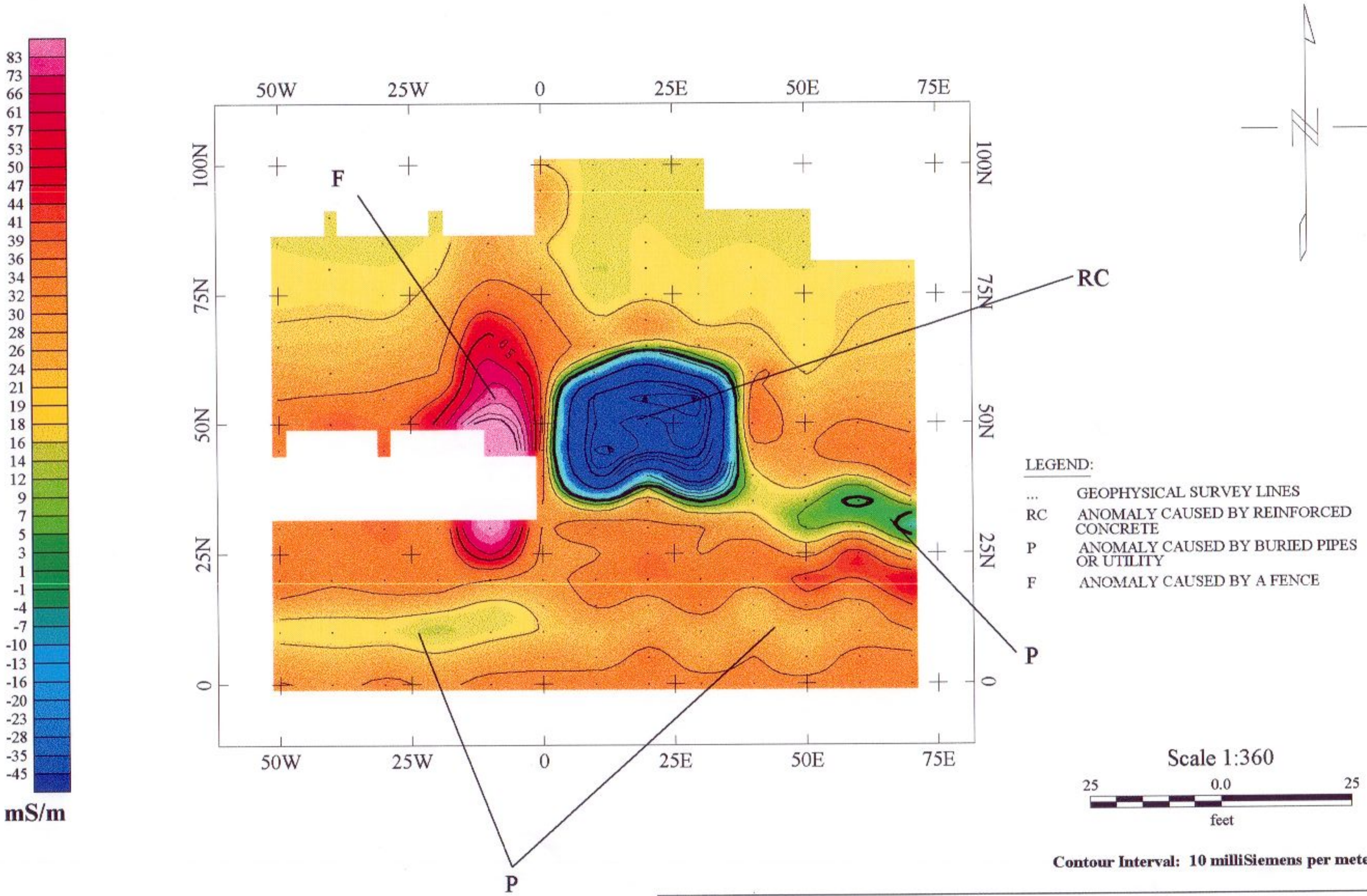


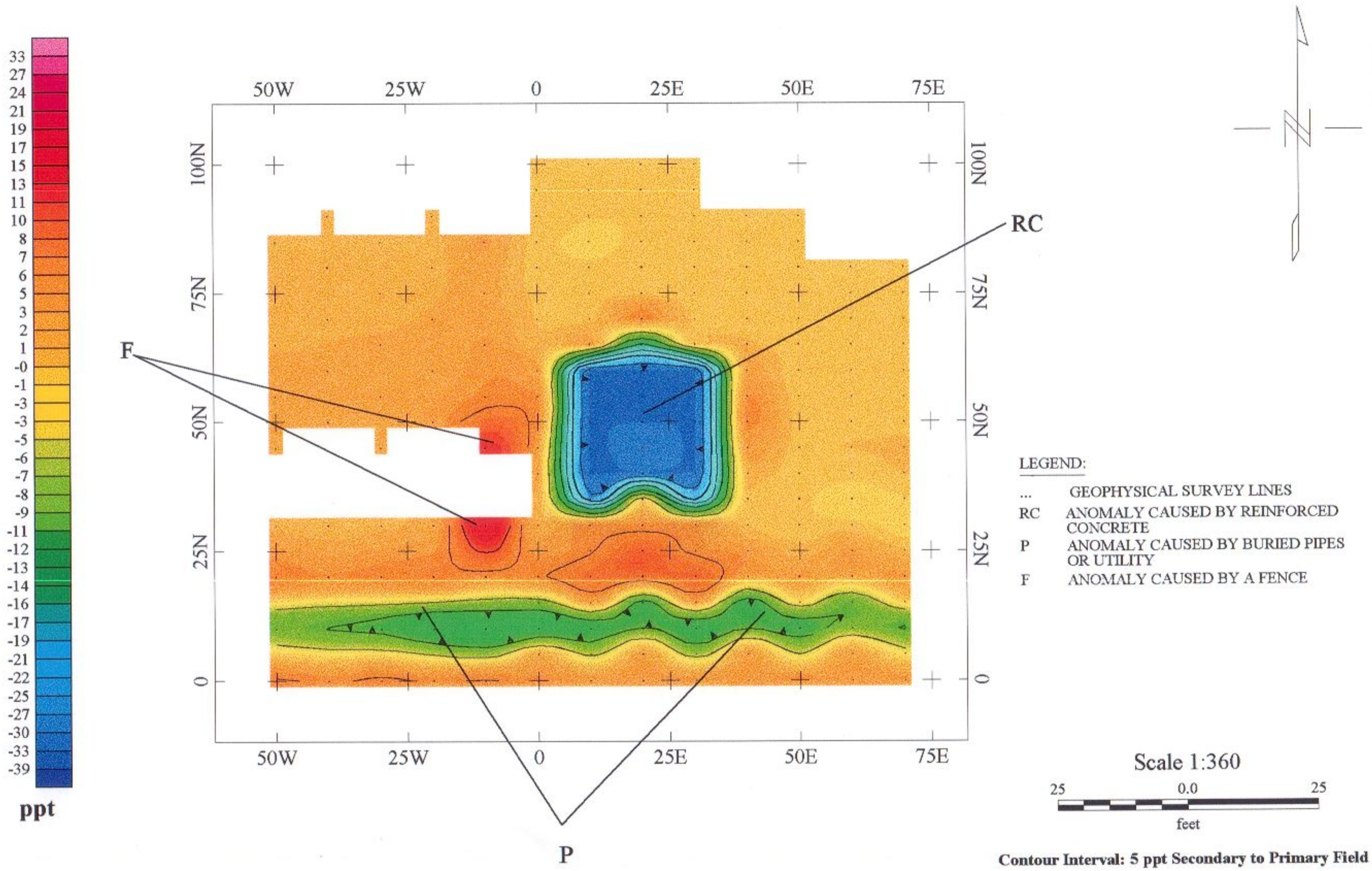
FIGURE A-6

FORT McCLELLAN
SITE - FORMER DECONTAMINATION COMPLEX BLDG 1271

EM31 CONDUCTIVITY
VERTICAL DIPOLE (3.0 FT ABOVE GROUND SURFACE)
N-S SURVEY LINES

GEOPHYSICS GROUP KNOXVILLE, TENNESSEE

NAME: Micki Maki	DATE: July 14, 1999
PROJECT NUMBER: 774645	LOCATION: C:\Projects\Fort McClellan\Decon\EM31\nc.map



Contour Interval: 5 ppt Secondary to Primary Field

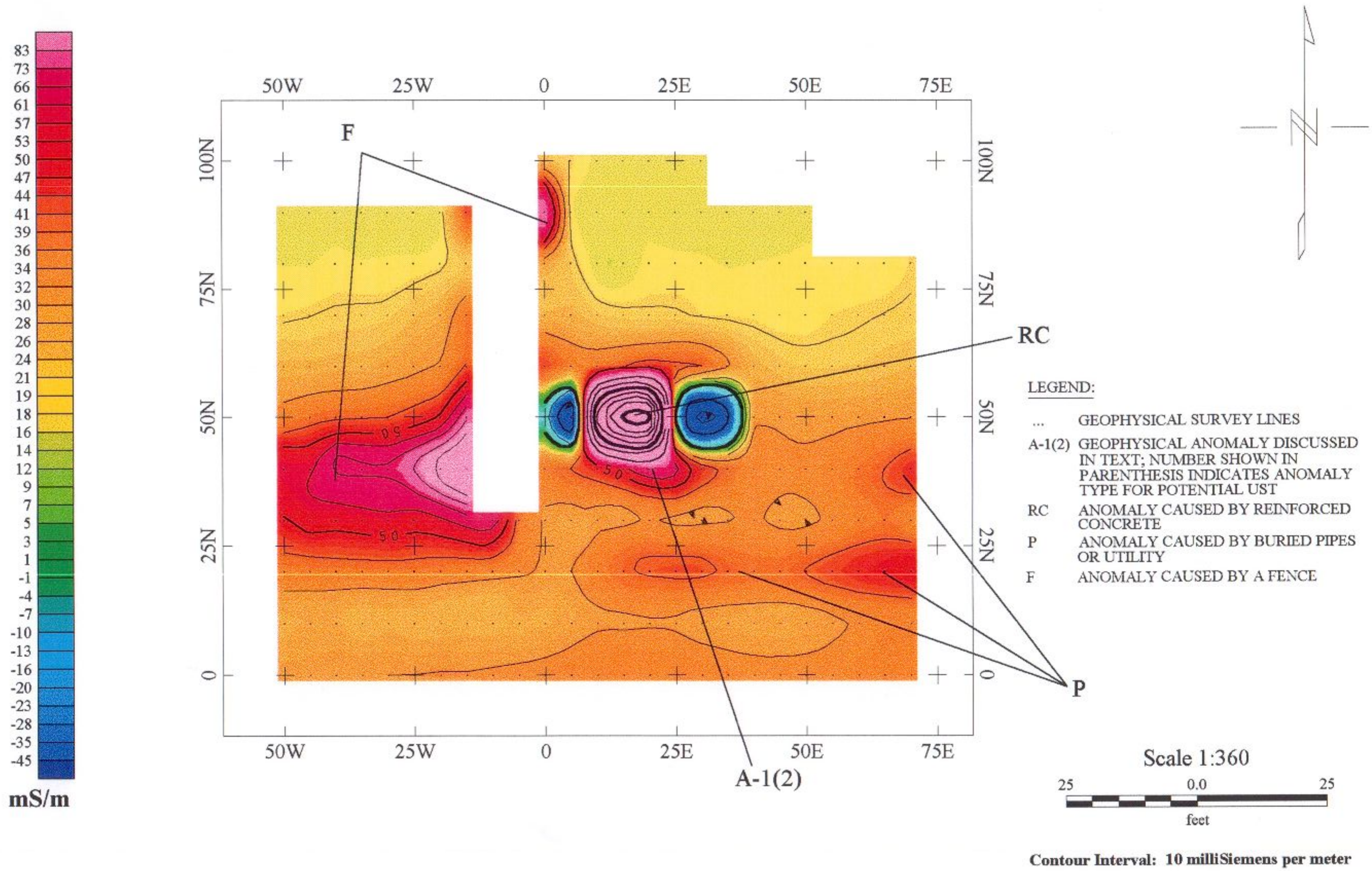
FIGURE A-7

FORT McCLELLAN
SITE - FORMER DECONTAMINATION COMPLEX BLDG 1271

EM31 IN-PHASE COMPONENT
VERTICAL DIPOLE (3.0 FT ABOVE GROUND SURFACE)
N-S SURVEY LINES

GEOPHYSICS GROUP KNOXVILLE, TENNESSEE

NAME: Micki Maki	DATE: July 14, 1999
PROJECT NUMBER: 774645	LOCATION: C:\Projects\Fort McClellan\Decon\EM31\ni.map



Contour Interval: 10 milliSiemens per meter

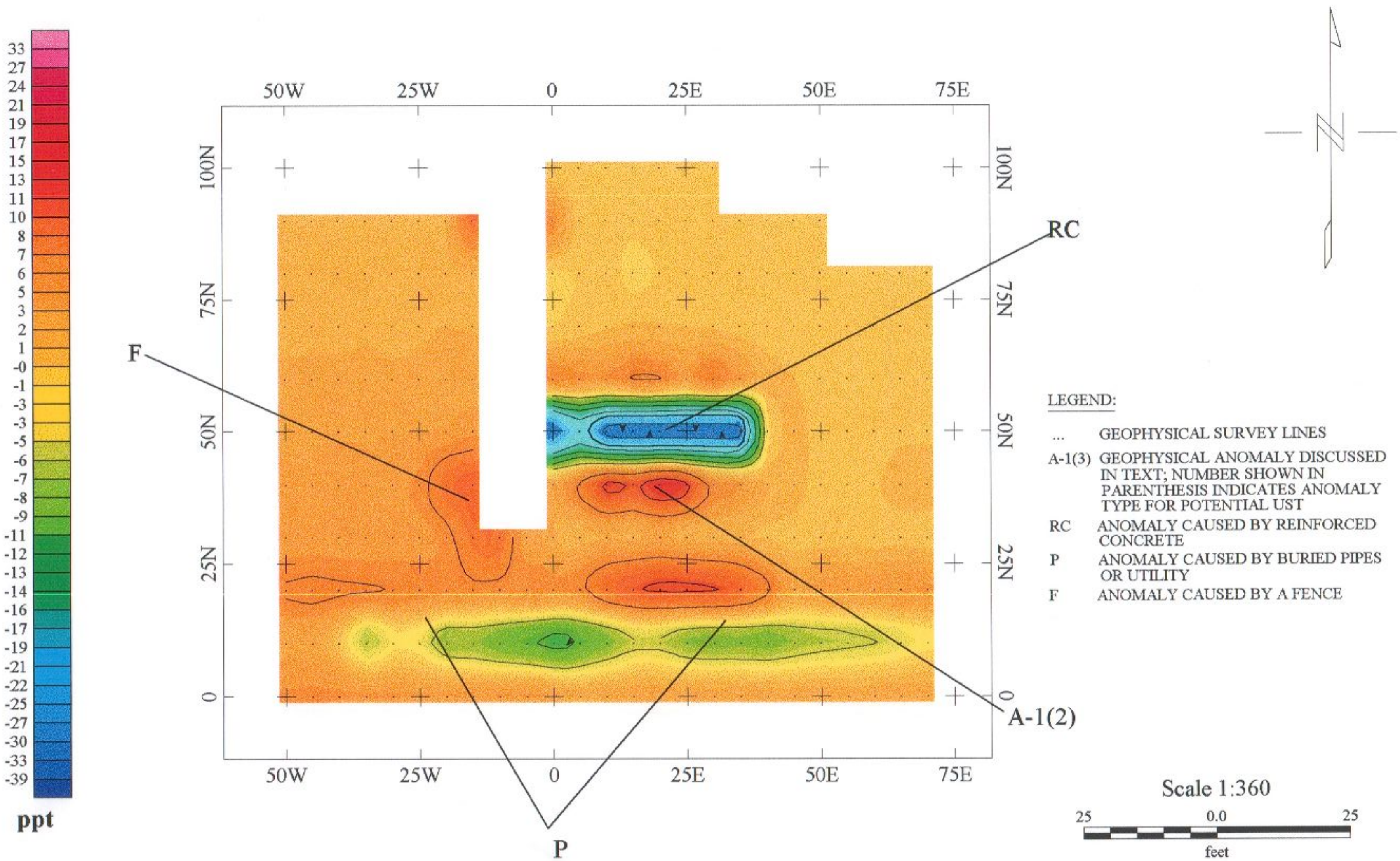
FIGURE A-8

FORT McCLELLAN
SITE - FORMER DECONTAMINATION COMPLEX BLDG 1271

EM31 CONDUCTIVITY
VERTICAL DIPOLE (3.0 FT ABOVE GROUND SURFACE)
E-W SURVEY LINES

GEOPHYSICS GROUP KNOXVILLE, TENNESSEE

NAME: Micki Maki	DATE: July 14, 1999
PROJECT NUMBER: 774645	LOCATION: C:\Projects\Fort McClellan\Decon\EM31\ec.map



Contour Interval: 5 ppt Secondary to Primary Field

FIGURE A-9

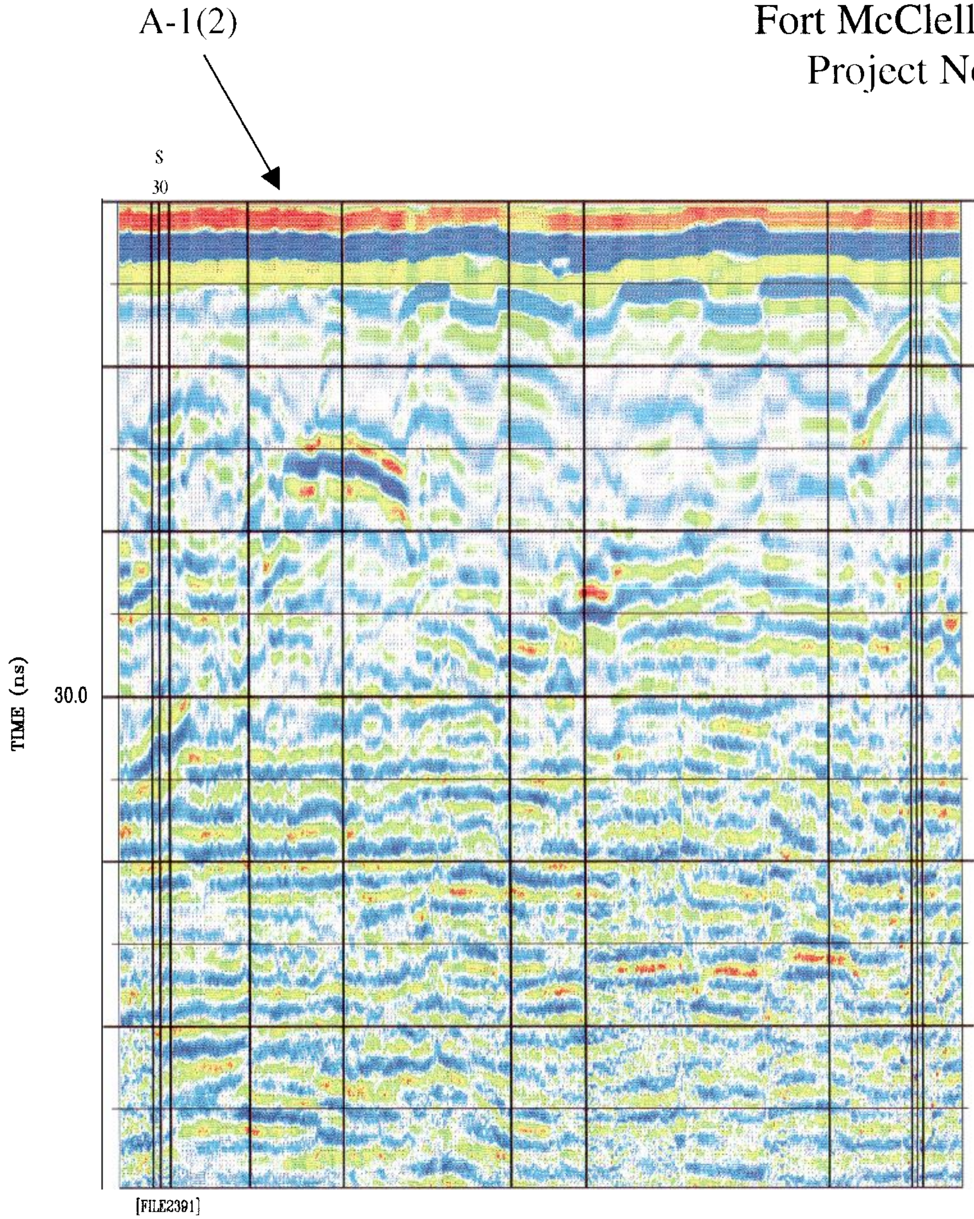
FORT McCLELLAN
SITE - FORMER DECONTAMINATION COMPLEX BLDG 1271

EM31 IN-PHASE COMPONENT
VERTICAL DIPOLE (3.0 FT ABOVE GROUND SURFACE)
E-W SURVEY LINES

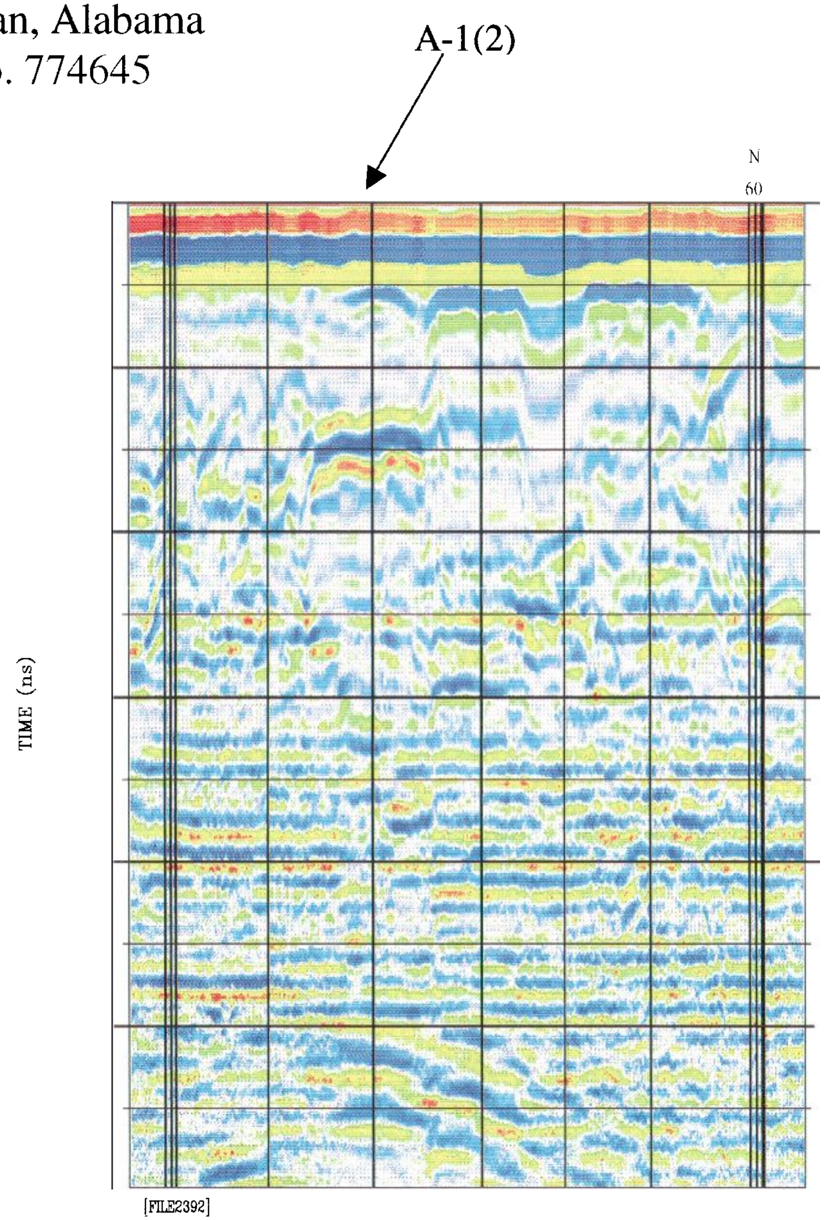
GEOPHYSICS GROUP KNOXVILLE, TENNESSEE

NAME:	DATE:
Micki Maki	July 14, 1999
PROJECT NUMBER:	LOCATION:
774645	C:\Projects\Fort McClellan\Decon\EM31\ei.map

Figure A-10
Former Decontamination Complex
Fort McClellan, Alabama
Project No. 774645

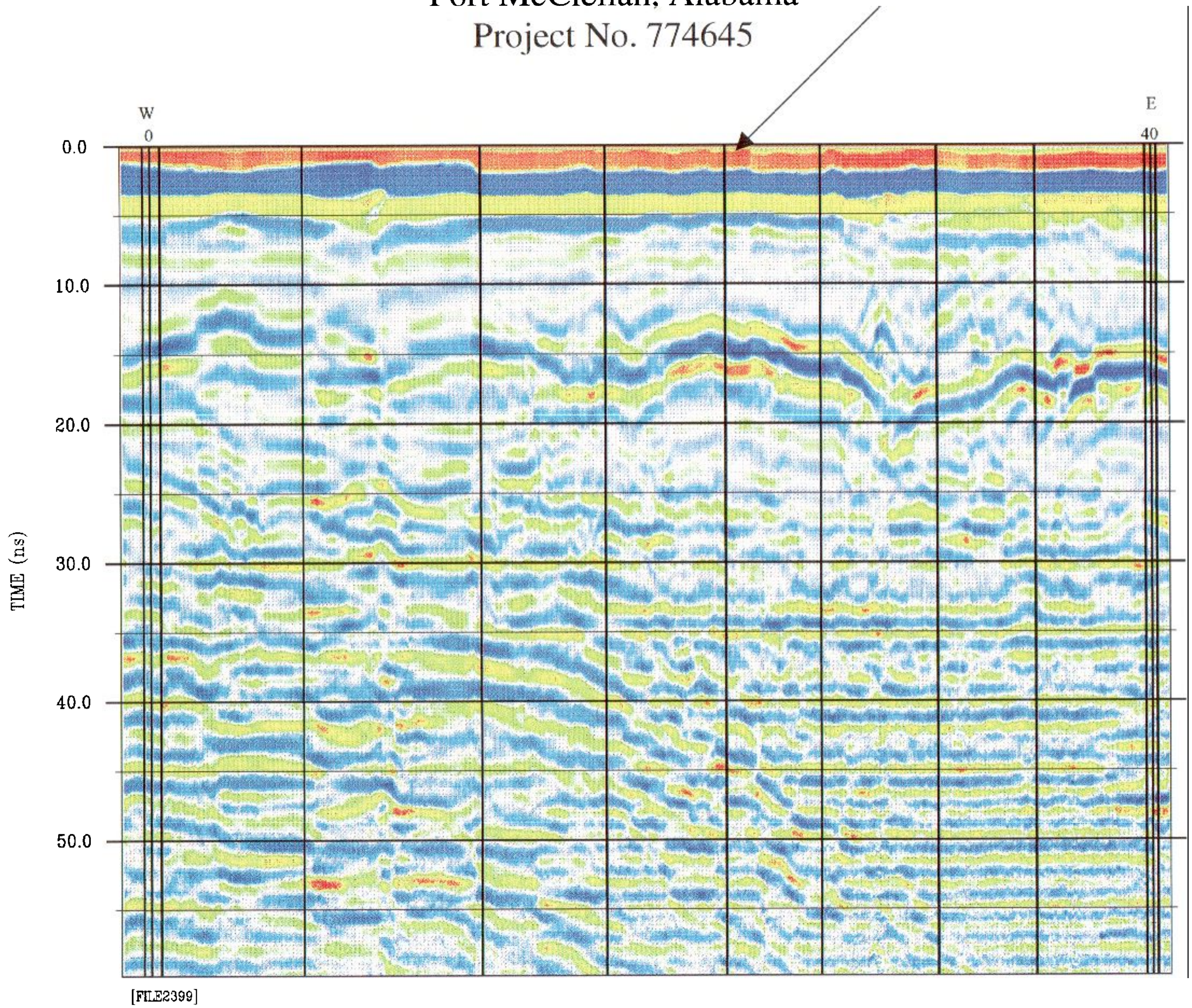


Line 20 E, 400 MHz Antenna



Line 25 E, 400 MHz Antenna

Figure A-11
Former Decontamination Complex
Fort McClellan, Alabama
Project No. 774645



Line 40 N, 400 MHz Antenna

ATTACHMENT

THEORETICAL BACKGROUND

Table of Contents

Page

List of Acronyms ii

1.0 Magnetic Method 1

2.0 Frequency-Domain EM Method 3

3.0 Time-Domain EM Method 5

4.0 Ground Penetrating Radar Method 7

5.0 References 10

List of Acronyms

EM	electromagnetic induction
EM31	Geonics Limited EM31 Terrain Conductivity Meter
EM61	Geonics Limited EM61 High-Resolution Metal Detector
G-856AX	Geometrics Inc. G-856AX Magnetometer
G-858G	Geometrics Inc. G-858G Magnetic Gradiometer
GPR	ground penetrating radar
GSSI	Geophysical Survey Systems Inc.
9860-BRL	Metrotech Inc. 9860-BRL EM utility locator
mV	millivolts
mS/m	millisiemens/meter
MHz	megahertz
nT	nanoteslas
nT/m	nanoteslas/meter
ppt	parts per thousand
RF	radiofrequency
UXO	unexploded ordnance

1.0 Magnetic Method

The magnetic instruments used during the Fort McClellan surface geophysical surveys were a Geometrics, Inc., G-858G "walking mode" magnetic gradiometer (G-858G) for acquiring survey data and a Geometrics, Inc., G-856AX magnetometer for collecting magnetic base station data.

The G-858G, which is an optically-pumped cesium vapor instrument, measures the intensity of the Earth's magnetic field in nanoteslas (nT) and the vertical gradient of the magnetic field in nanoteslas per meter (nT/m). The vertical gradient is measured by simultaneously recording the magnetic field with two sensors at different heights. To determine the vertical magnetic gradient, the upper sensor reading is subtracted from the lower sensor reading, and the result is then divided by the distance between the sensors. The distance between sensors for this investigation was 2.5 feet (0.76 meters). The vertical magnetic gradient measurement allows for better definition of shallower anomalies.

During operation of the G-858G magnetic gradiometer, a direct current is used to generate a polarized monochromatic light. Absorption of the light occurs within the naturally precessing cesium atoms found in the instrument's two vapor cells or sensors. When absorption is complete, the precessing atoms become a transfer mechanism between light and a transverse radiofrequency (RF) field at a specific frequency of light known as the Larmor frequency. The light intensity is used to monitor the precession and adjusts the RF allowing for the determination of the magnetic field intensity (Sheriff, 1991).

The Earth's magnetic field is believed to originate in currents in the Earth's liquid outer core. The magnetic field varies in intensity from approximately 25,000 nT near the equator, where it is parallel to the Earth's surface, to approximately 70,000 nT near the poles, where it is perpendicular to the Earth's surface. In Alabama, the intensity of the Earth's magnetic field varies from 50,000 nT to 51,000 nT and has an associated inclination of approximately 54 degrees.

Anomalies in the Earth's magnetic field are caused by induced or remnant magnetism. Remnant magnetism is caused by naturally occurring magnetic materials. Induced magnetic anomalies result from the induction of a secondary magnetic field in a ferromagnetic material (e.g., pipelines, drums, tanks, or well casings) by the Earth's magnetic field. The shape and amplitude of an induced magnetic anomaly over a ferromagnetic object depend on the geometry, size, depth, and magnetic susceptibility of the object and on the magnitude and inclination of the Earth's magnetic field in the study area (Dobrin, 1976; Telford, et al., 1976). Induced magnetic anomalies over buried objects such as drums, pipes, tanks, and buried metallic debris generally exhibit an asymmetrical, south high/north low signature (maximum amplitude on the south side and minimum on the north in the Northern Hemisphere). Magnetic anomalies caused by buried metallic objects generally have dimensions much greater than the dimensions of the objects themselves. As an extreme example, a magnetometer may begin to sense a buried oil well casing at a distance of greater than 50 feet.

The magnetic method is not as effective as other geophysical techniques in areas with ferromagnetic material at the surface because the signal from the surface material often obscures the signal from buried objects. Also, the presence of an alternating current electrical power source can render the signal immeasurable because of the high precision required in the measurement of the frequency at which the protons precess (Breiner, 1973). The precession signal may also be sharply degraded in the presence of large magnetic gradients (exceeding approximately 600 nT/m).

The magnetic field measured at any point on the Earth's surface undergoes low-frequency diurnal variation, called magnetic drift, associated with the Earth's rotation. The source of magnetic drift is mainly within the ionosphere, and its magnitude is sometimes large enough to introduce artificial trends in survey data. The G-856AX base station magnetometer was used to record this drift for removal from the G-858G survey data during processing.

Applications of the magnetic method include delineating old waste sites and mapping unexploded ordnance (UXO), drums, tanks, pipes, abandoned wells, and buried metallic debris. The method also is useful in searching for magnetic ore bodies, delineating basement rock, and mapping subsurface geology characterized by volcanic or mafic rocks.

2.0 Frequency-Domain EM Method

Frequency-domain electromagnetic induction equipment used during this investigation consisted of a Geonics EM31 terrain conductivity meter (EM31) coupled to an Omnidata DL720 digital data logger. The EM31 consists of a 12-foot-long plastic boom with a transmitter coil mounted at one end and a receiver coil at the other. An alternating current is applied to the transmitter coil, causing the coil to radiate a primary EM field. As described by Faraday's law of induction, this time-varying magnetic field generates eddy currents in conductive subsurface materials. These eddy currents have an associated secondary magnetic field with a strength and phase shift (relative to the primary field) that are dependent on the conductivity of the medium. The combined effect of the primary and secondary fields is measured by the receiver coil in-phase (in-phase) and 90 degrees out-of-phase (quadrature) with the primary field. Most geologic materials are poor conductors. Current flow through geologic materials takes place primarily in the pore fluids (Keller and Frischknecht, 1966); as such, conductivity is predominantly a function of soil type, porosity, permeability, pore fluid ion content, and degree of saturation. The EM31 is calibrated so that the out-of-phase component is converted to electrical conductivity in units of millisiemens per meter (mS/m) (McNeill, 1980), and the in-phase component is converted to parts per thousand (ppt) of the secondary field to the primary EM field. The in-phase component is a relative value that is generally set to zero over background materials at each site.

The depth of penetration for EM induction instruments depends on the transmitter/receiver separation and coil orientation (McNeill, 1980). The EM31 has an effective exploration depth of approximately 18 feet when operating in the vertical dipole mode (horizontal coils). In this mode, the maximum instrument response results from materials at a depth of approximately two-fifths the coil spacing (or, approximately 2 feet below ground surface with the instrument at the normal operating height of approximately 3 feet), providing that no large metallic features such as tanks, drums, pipes, and reinforced concrete are present. Single buried drums typically can be located to depths of approximately 5 feet, whereas clusters of drums can be located to significantly greater depths if background noise is limited or negligible. In the horizontal dipole mode (vertical coils), the EM31 has an effective exploration depth of approximately 9 feet and is most sensitive to materials immediately beneath the ground surface.

The EM31 generally must pass over or very near a buried metallic object to detect it. Both the out-of-phase and in-phase components exhibit a characteristic anomaly over near-surface metallic conductors. This anomaly consists of a narrow zone having strong negative amplitude centered over the target and a broader lobe of weaker, positive amplitude on either side of the target. For long, linear conductors such as pipelines, the characteristic anomaly is as described when the axis of the coil (instrument boom) is at an angle to the conductor. However, when the instrument boom is oriented parallel to the conductor, a positive amplitude anomaly is observed. The application of frequency-domain EM techniques includes mapping conductive groundwater contaminant plumes in very shallow aquifers, delineating oil brine pits, landfill boundaries and pits and trenches containing buried metallic and nonmetallic debris, and locating buried pipes, cables, drums, and tanks.

3.0 Time-Domain EM Method

Time-domain electromagnetic induction equipment used during this investigation consisted of a Geonics EM61 high-resolution metal detector (EM61) coupled to an Omnidata DL720 digital data logger. The EM61 consists of one transmitter and two receiver coils each 1-meter square. The transmitter and one receiver coil are co-incident within the instrument, the second receiver coil is separated by 0.5 meters. Comparison of the readings in the two receiver coils allows for discrimination between shallow and deeply buried metal objects. In operation, a pulse of current in the transmitter coil generates a primary magnetic field that induces eddy currents in nearby metallic conductors, as described by Faraday's law of induction. These eddy currents produce secondary magnetic fields that are measured by the time-dependant, decaying voltage they produce in the receiver coils. The internal electronics of the EM61 are designed such that readings are taken in a very narrow time window following transmitter turn-off. The measurement of secondary fields in the absence of a primary field allows for the higher sensitivity measurements relative to frequency-domain EM systems. Since the current ring diffuses down and outward, readings taken immediately after current shut-off are most affected by near-surface conditions and the later readings by the electrical properties of the deeper subsurface.

The EM61 is generally adjusted in the field to have a zero millivolts (mV) response over background conditions.

The EM61 depth of penetration depends primarily on the size of the target, and to a lessor degree on the type of metal (Geonics, 1997). The EM61 has an effective exploration depth in excess of 10 feet for locating large conductive features, such as tanks.

The EM61 generally must pass over, or very, near a buried metallic object to detect it. The EM61 characteristic anomaly consists of readings elevated 10 to 20 mV above background for small conductors and up to several thousand mV for large conductors, such as tanks. For mapping long, linear conductors, the EM61 data is most useful when measurements are taken perpendicular to the orientation of the conductor.

The application of near-surface time-domain EM techniques with instruments such as the EM61, includes detecting and mapping metallic objects (UXO, buried pipes, cables, drums, and tanks), and mapping the boundaries of landfill, pits or trenches containing buried metallic debris.

4.0 Ground Penetrating Radar Method

Ground penetrating radar (GPR) equipment used during this investigation consisted of a Geophysical Survey Systems, Inc. (GSSI) Model SIR-2P equipped with 200- and 400-megahertz (MHz) monostatic antennas, and a DPU-5400 high-resolution thermal gray-scale printer.

When conducting a GPR survey, an antenna containing both a transmitter and a receiver is pulled along the ground surface. The transmitter radiates short pulses of high-frequency (center frequencies in the range of 200 to 400 MHz) EM energy into the ground. The EM wave propagates into the subsurface at a velocity determined by the electromagnetic properties (primarily dielectric constant) of the medium through which the wave travels. When the wave encounters the interface of two materials having different electromagnetic properties, such as between soil and an underground storage tank (UST), a portion of the energy is reflected back to the surface where the receiver measures its amplitude and time of arrival. The magnitude of the reflection is an indication of the degree of contrast in the electrical properties of the interface producing the reflection. Greater contrasts generally produce higher amplitude reflections. The time of the reflection arrival indicates the relative depth of the source of the reflection. The reflection is often seen as a characteristic triplet that is the result of the receiving antenna response and of multiples generated along the propagation path. The received signal is transmitted to a control unit, displayed on a color monitor, and saved on the control unit's digital hard drive.

As predicted by Maxwell's equations for a propagating EM wave, two kinds of charge flow are generated by the associated alternating electric and magnetic fields (Ulriksen, 1982). The charge flows are conduction and displacement currents. The conduction current term is predominant at lower frequencies, and conduction currents are used in the EM induction method. At the higher frequencies used in the GPR method, the displacement current term becomes predominant because the high frequencies will set bound charges in motion, causing polarization.

The physical properties that describe the movement of charges by conduction and displacement currents are the conductivity and the dielectric constant of the medium, respectively. Conductivity is a measure of the ease with which charges and charged particles move freely through the medium when subjected to an external electric field. The dielectric constant, or its value normalized by the dielectric constant of free space called the relative dielectric constant, is a measure of how easily a medium polarizes to accommodate the EM fields of a propagating wave (Keller and Frischknecht, 1966).

Although conductivity has a smaller effect on the transmission of EM waves emitted from a GPR unit, it has an important effect on the attenuation of the waves (Ulriksen, 1982). Highly conductive media will attenuate the EM signal rapidly and restrict depth penetration to the first several feet. Highly resistive (poorly conductive) media allow deeper penetration. The frequency of the transmitted waves also affects the depth of penetration. Base on the electromagnetic skin depth relationship, lower frequencies penetrate deeper but have lower resolution, whereas higher frequencies can resolve smaller objects and soil layers at the expense of depth penetration. At many sites in the southeastern U.S., heavy clay soils are relatively conductive and depth of penetration is often limited to 5 feet or less. At some sandy sites, typical of coastal regions, GPR depth of penetration often exceeds 10 to 15 feet.

In unconsolidated materials, conduction occurs predominantly through pore fluids (Keller and Frischknecht, 1966). Therefore, changes in pore fluid content, porosity, permeability, and degree of saturation will affect reflected and refracted EM signals. Backfilled trenches, in which there may be different compaction densities relative to the surrounding area, can be identified by low to moderate amplitude reflections. When the target of a GPR survey is a metallic conductor such as metal pipes and cables, drums, tanks, or ammunition shells, the reflections have high amplitudes because of the nearly complete reflection of the EM wave from the metallic conductor. Thus, the property of total reflection makes metallic targets well suited for detection within the range of the GPR unit. Reflections typically do not occur from below the metallic conductor, although multiples are common. The edges of metallic reflectors will generally exhibit diffraction patterns as a result of the transmitting and the receiving antennae being unfocused and emitting and receiving from a 45-degree cone. The cone causes the radar to receive reflections from objects that are ahead of it, at times later than an object at the same depth directly below the antennae. As the radar approaches an object, the reflection becomes earlier in time, with the earliest reflection taking place when the radar is directly above the object. A complimentary pattern occurs as the antenna moves away from the object, resulting in the characteristic hyperbolic shaped anomaly on GPR profiles characteristic of small, subsurface metallic objects.

Applications of GPR include delineation of pits and trenches containing metallic and nonmetallic debris; location of buried pipes, drums, and USTs; and mapping of landfill boundaries, organic contaminant plumes, and near-surface geology.

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